Observations of SNRs and TeV Unidentified Sources with Suzaku

Contents:

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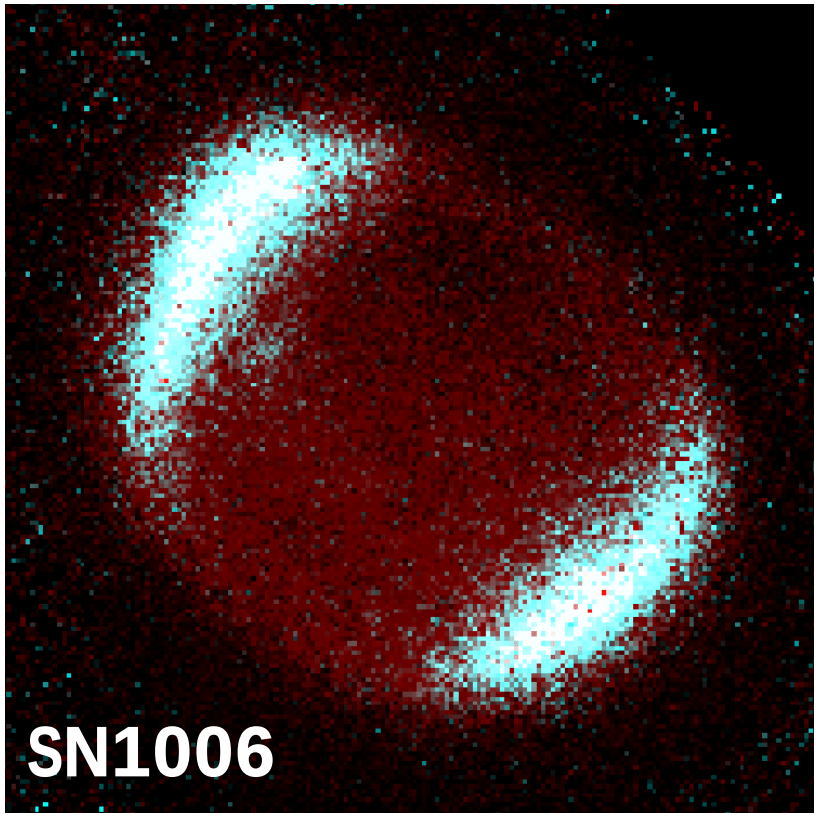
(ISAS/JAXA -> DIAS (Nov. 01))

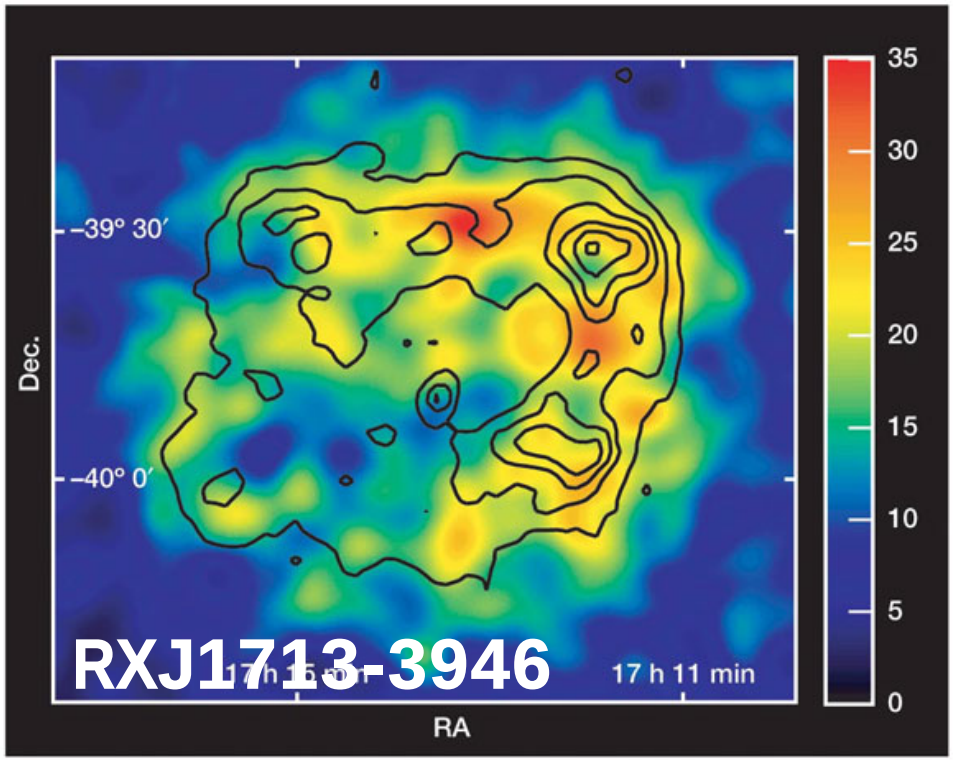
0. Observational clues of CR acceleration at SNRs

synchrotron X-ray



Discovered by ASCA
(Koyama+95)

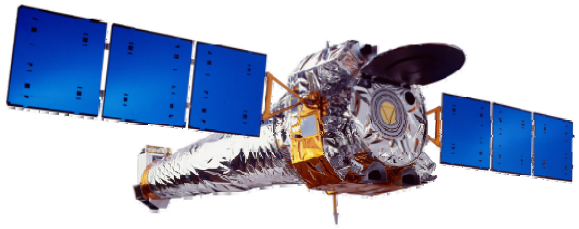
TeV gamma-ray



Discovered by HESS
(Aharonian+04)

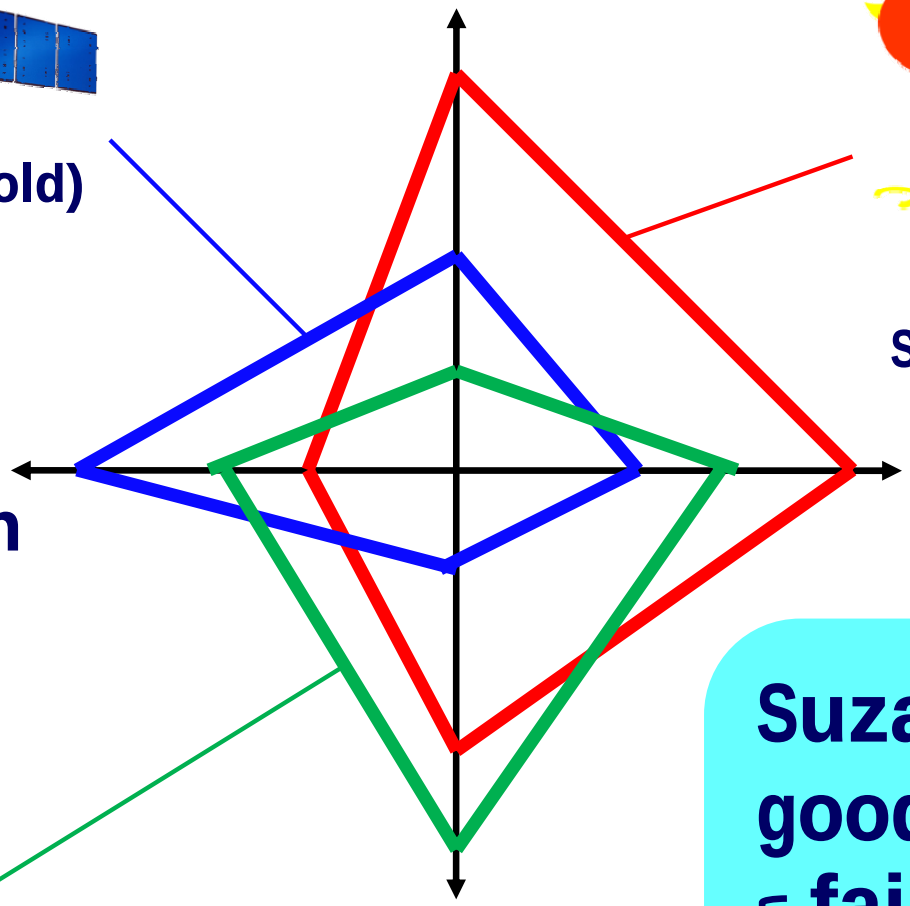
Shocks of SNRs accelerate cosmic rays !

New generation X-ray satellites



Chandra (10 years old)

Suzaku (4 years old)



XMM (10 years old)

Suzaku is good at observing
- **faint**
- **diffuse** **sources**
- **hard**

Ideal for SNRs and TeV unIDs

Remaining problems for Suzaku (Contents of this talk)

1. Estimating Maximum energy

Can we expect the E_{max} of accelerated particles ?
Is it larger/smaller than the knee energy ?

2. Can we “observe” proton accelerators ?

The main goal of cosmic ray physics in 100 years.
Not yet, but we are finding some clue.
It should be the golden age now
to study cosmic rays !

1. Estimating Maximum energy

How to estimate the maximum energy ?

We can use the cut-off of synchrotron X-rays

$h\nu \sim E_{max}B^2$ (Reynolds+98)

$h\nu \sim v_s^2\eta^{-1}$ (Zirakashvilli+07)

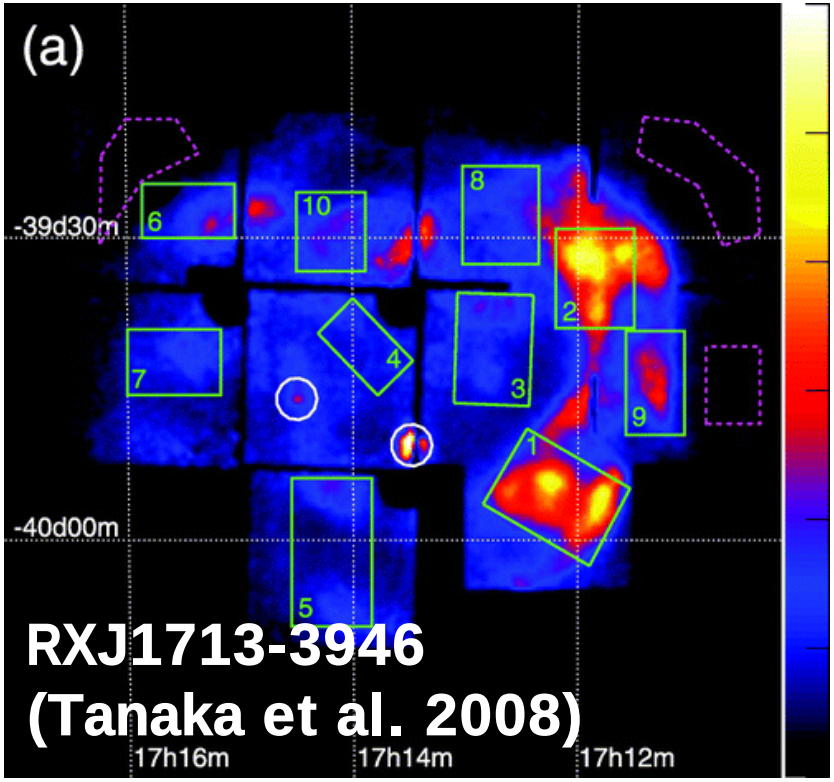
Not exponential cut-off ? (Vink+08)

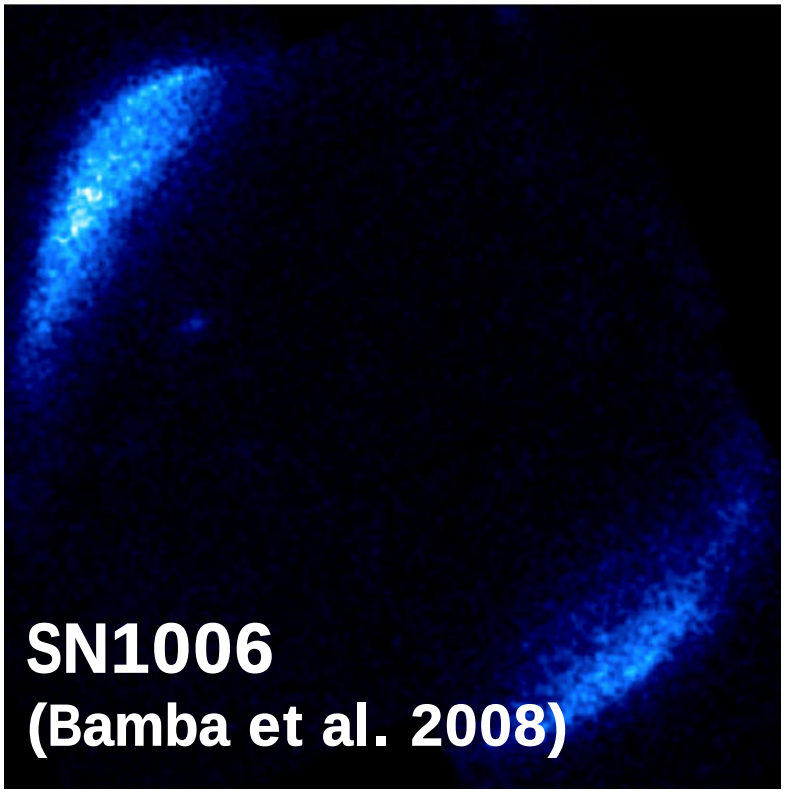
Spectral bending is reported only a few SNRs.

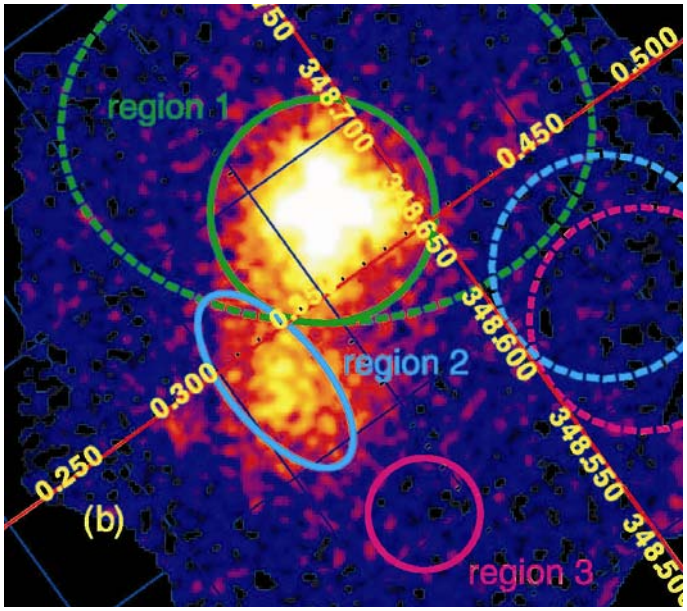
We need wide-band spectra with good statistics!

-> Suzaku observations

Suzaku observations of SNRs



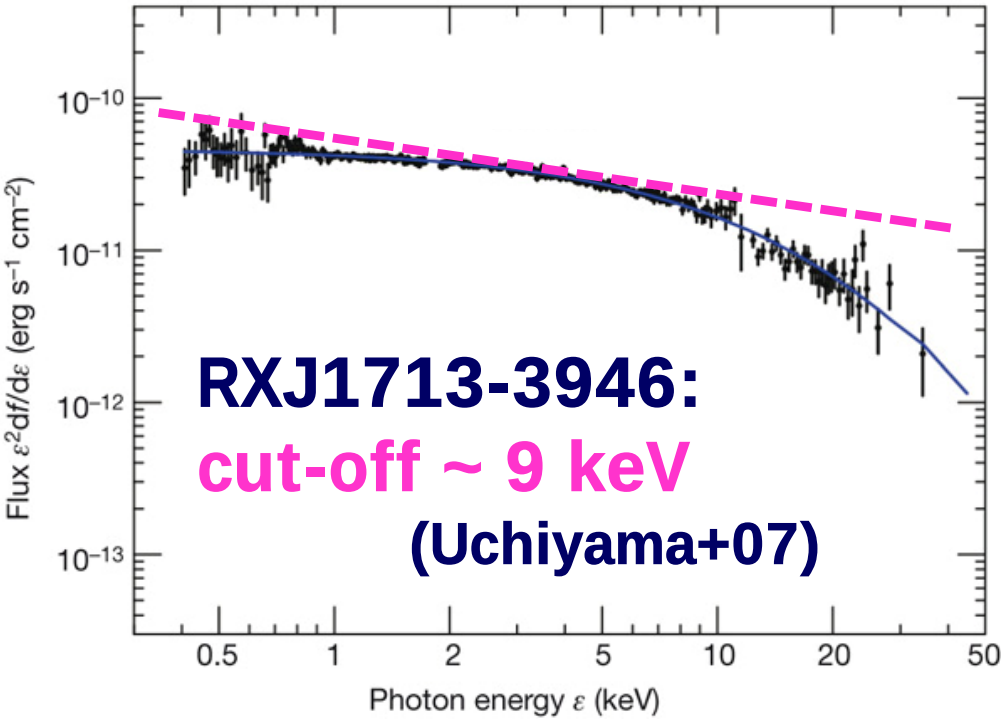


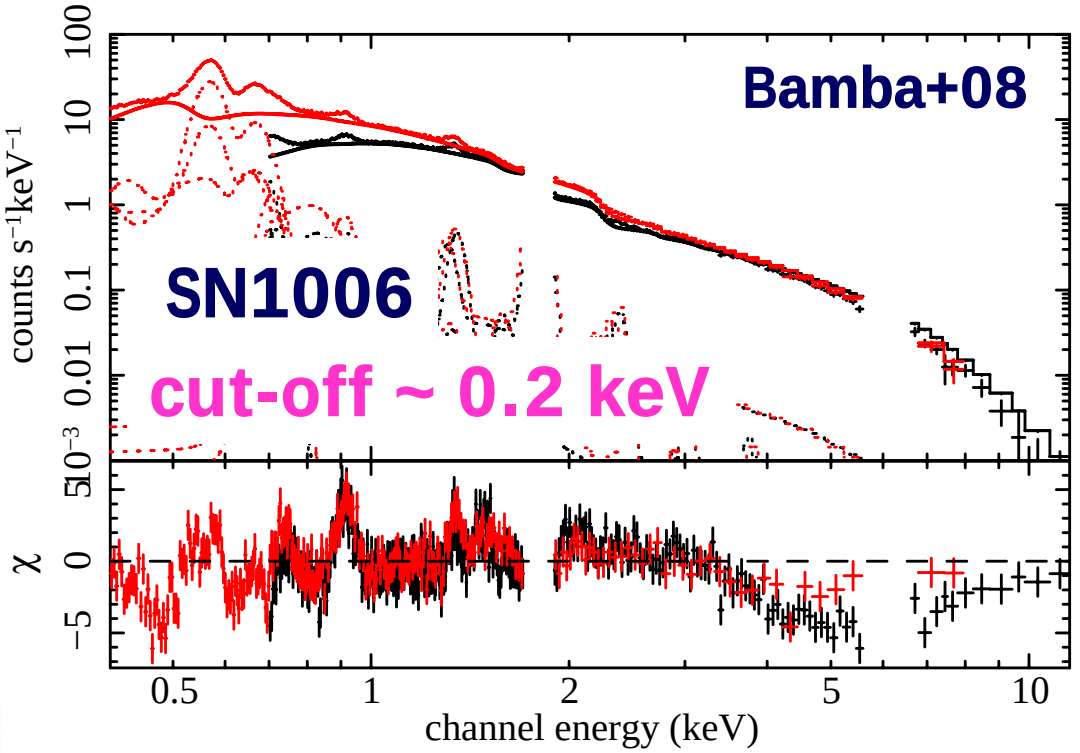


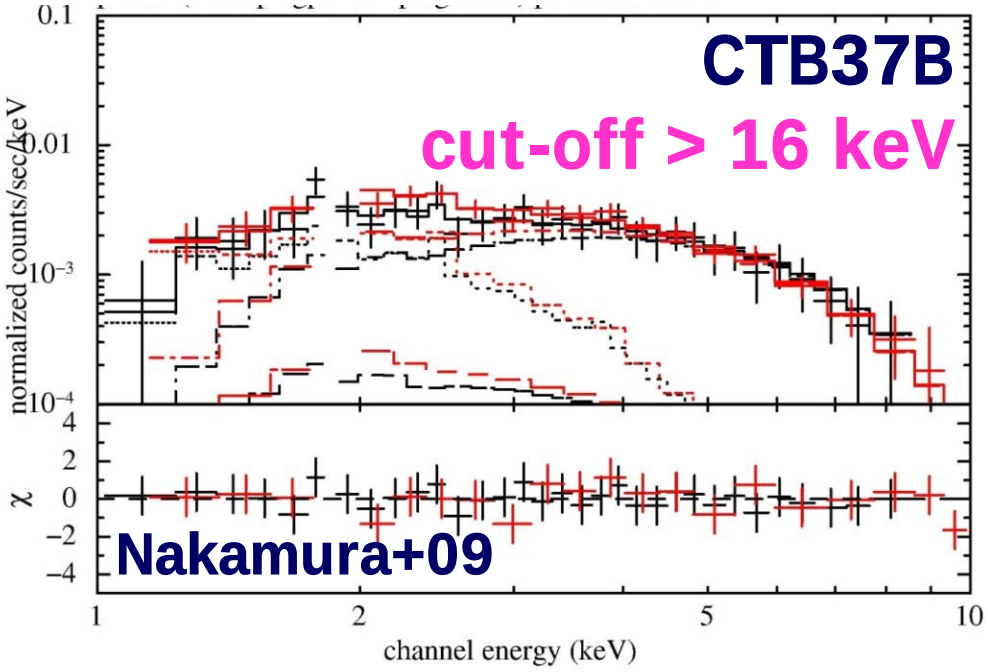
Suzaku has sensitivity in wide band and detected synchrotron X-rays from several SNRs

CTB37B
(Nakamura et al. 2009)

cut-off energy determined by Suzaku





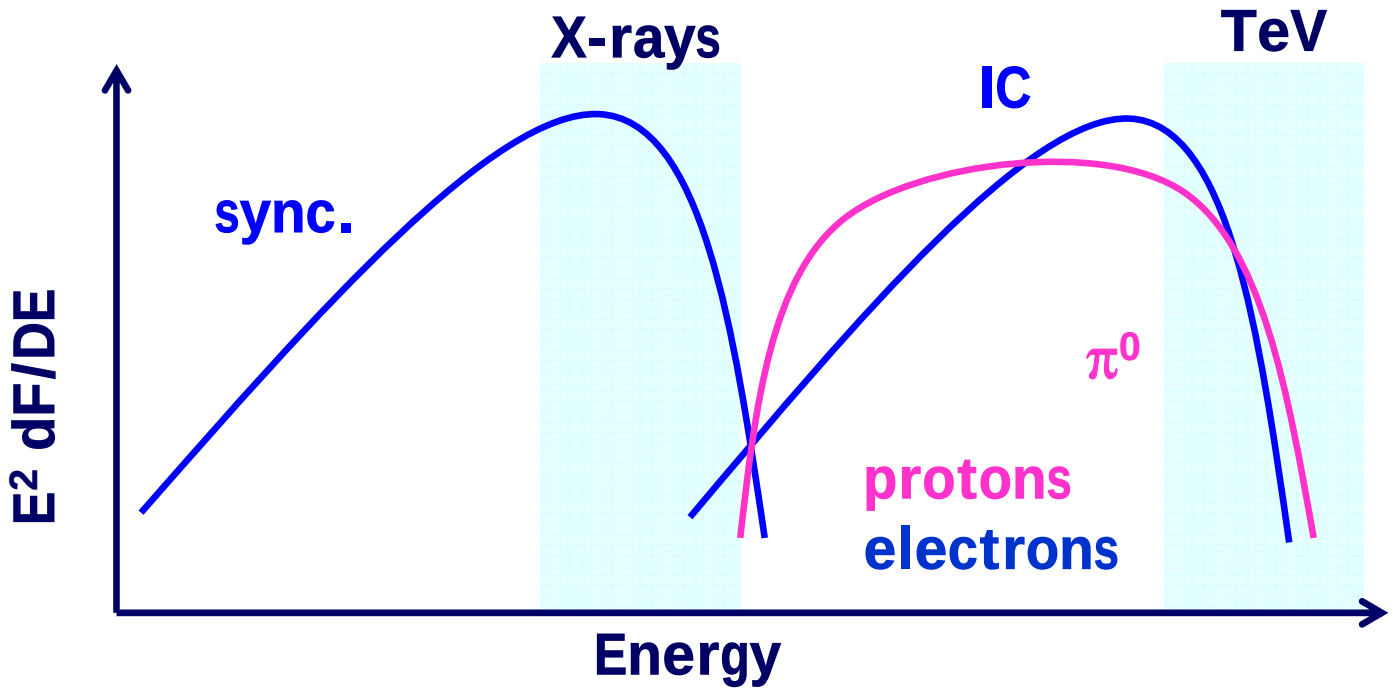


Suzaku detected cut-off of sync. X-rays
cut-off ~ 0.2 - 10 keV

1st conclusion:
E_{max} ~ 10-100TeV ?
E_{max} for p should be higher

2. Possible proton accelerators

How to search for p accelerators ?

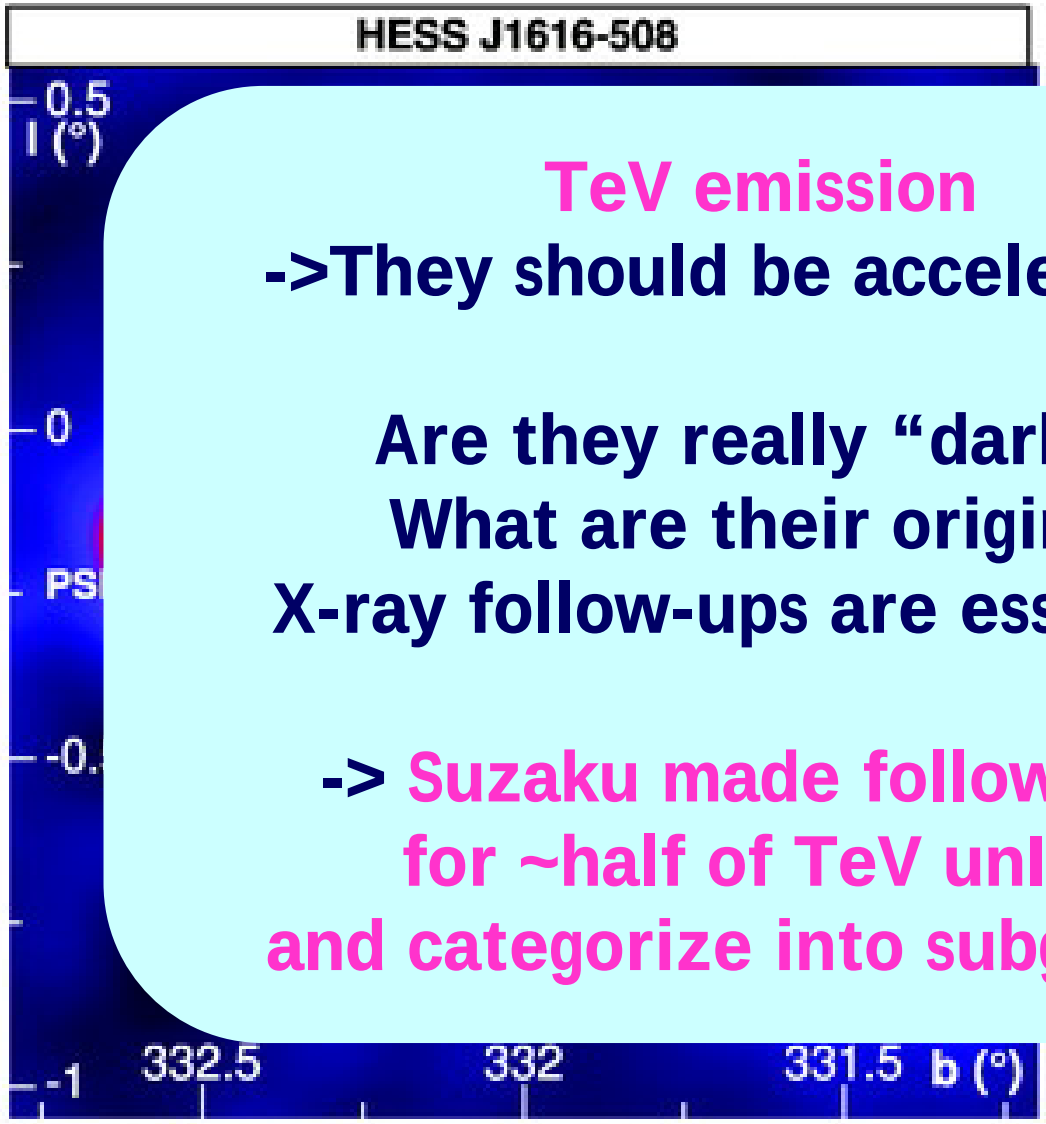


X-ray obs. cannot see protons.
Gamma-ray obs. cannot distinguish e and p.

We need both observations.
Do we have sources with only TeV gamma-rays ?

TeV-bright and X-ray faint sources ?

HESS discovered a lot of new sources on the Galactic plane



(Aharonian+06)

TeV emission
->They should be accelerators

Are they really "dark"?
What are their origin ?
X-ray follow-ups are essential

-> Suzaku made follow-ups
for ~half of TeV unIDs
and categorize into subgroups

he Galactic plane
e are diffuse

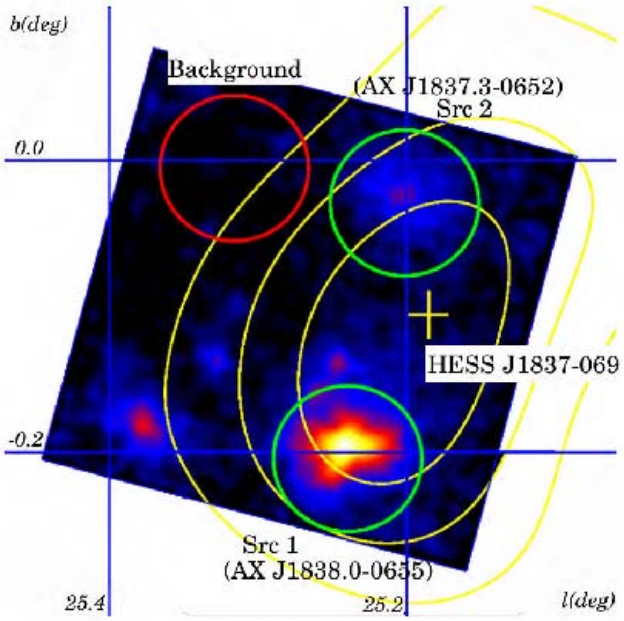
ctic sources

However,
y have no CP!

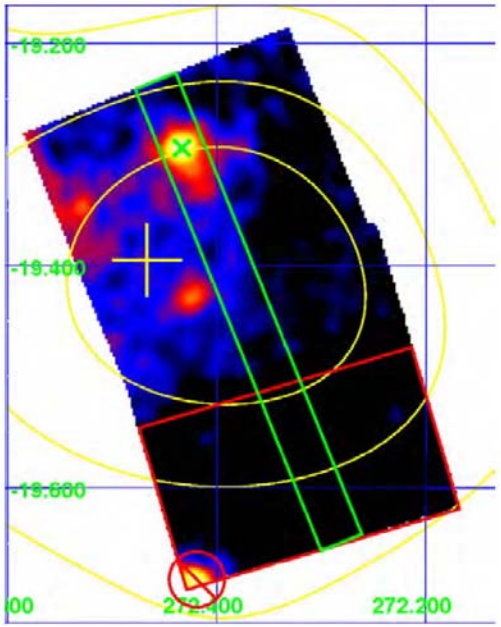
not
wn PSRs, PWNe
wn SNRs
nown SF regions

"TeV unID sources"
"dark particle accelerators"

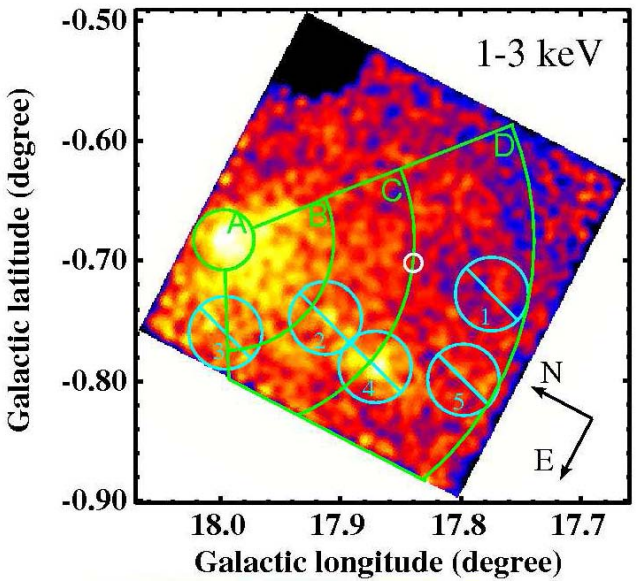
Group 1: Compact (+surrounding diffuse) sources



HESS J1837-069
(Anada+08)



HESS J1809-193
(Anada+09)



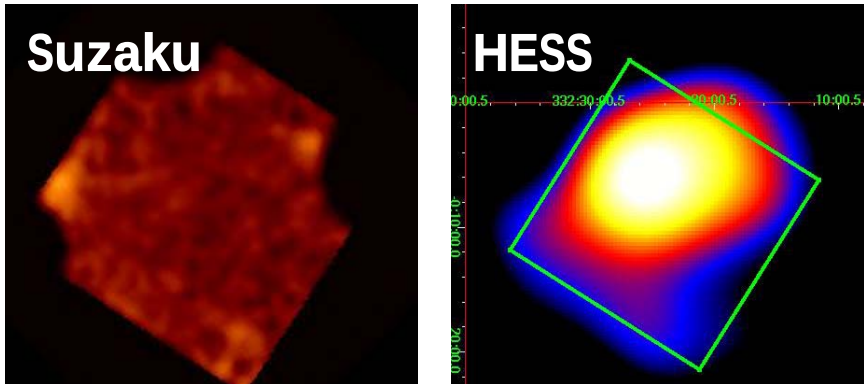
HESS J1825-137
(Uchiyama+09)

Spectra are very hard (Gamma ~ 1 – 2)
Compact source; 1837 has pulsation (70ms)

They should be pulsars and pulsar wind nebulae
We have many samples of PWN candidates

Group 2. Nothing found on the TeV peak -> dark particle accelerators

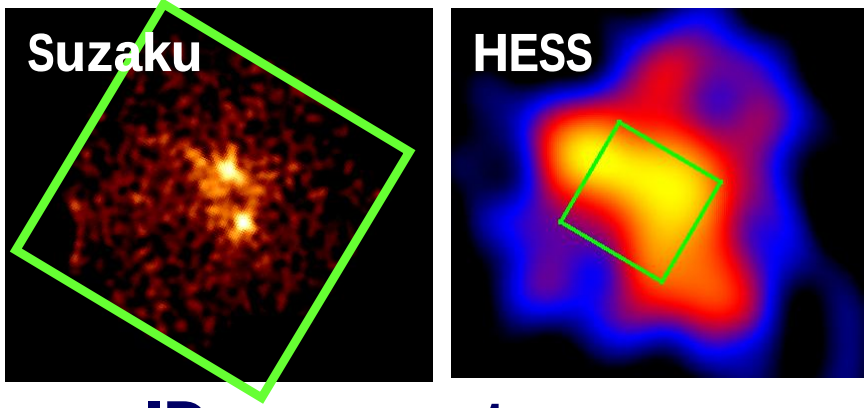
HESSJ 1616-508 (Matsumoto+07)



upper-limit !

$F_{TeV}/F_X > 55$

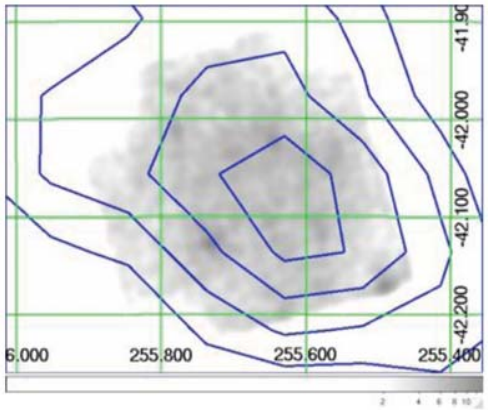
HESS J1804-216 (Bamba+07)



unID compact sources

$F_{TeV}/F_X > 13$

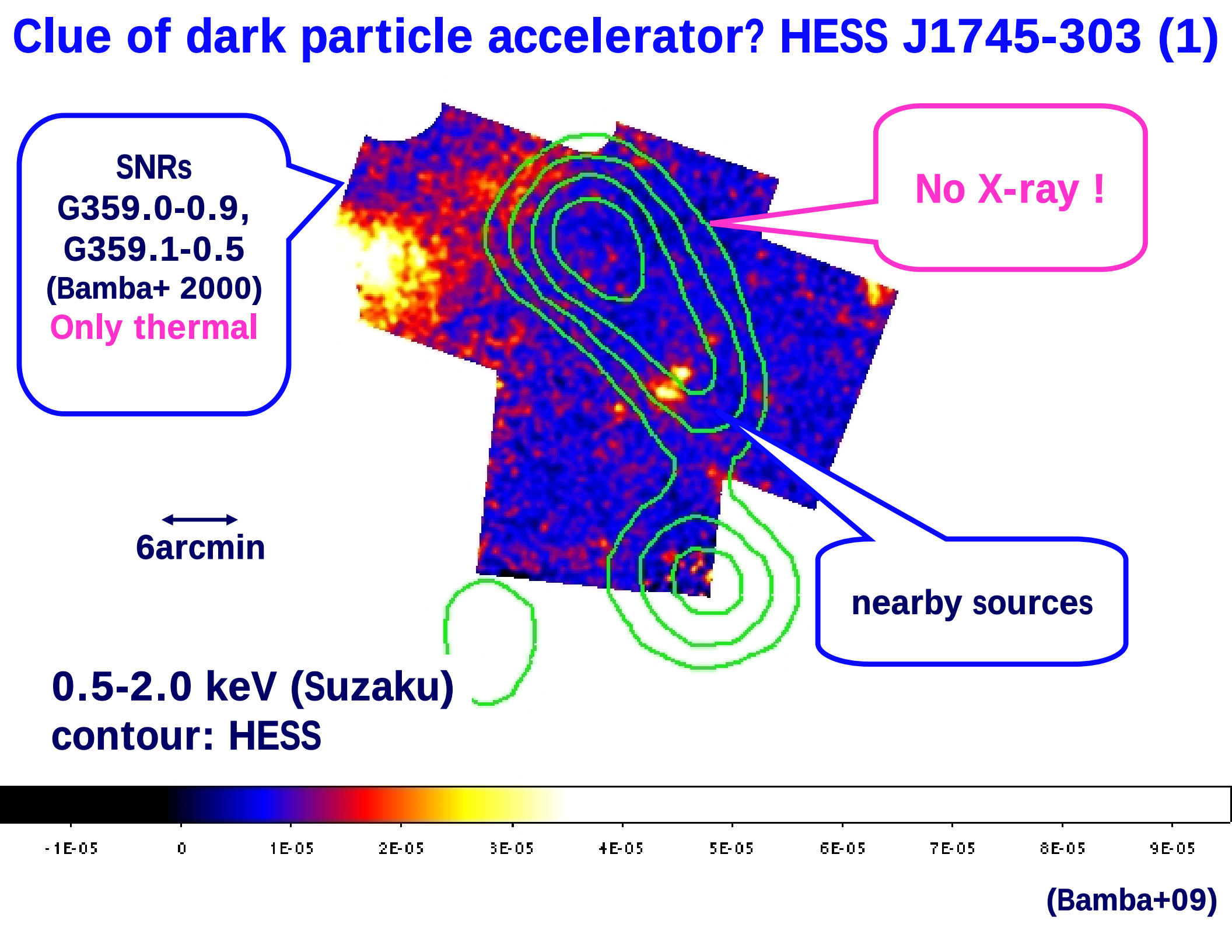
HESS J1702-420 (Fujinaga+ in prep.)



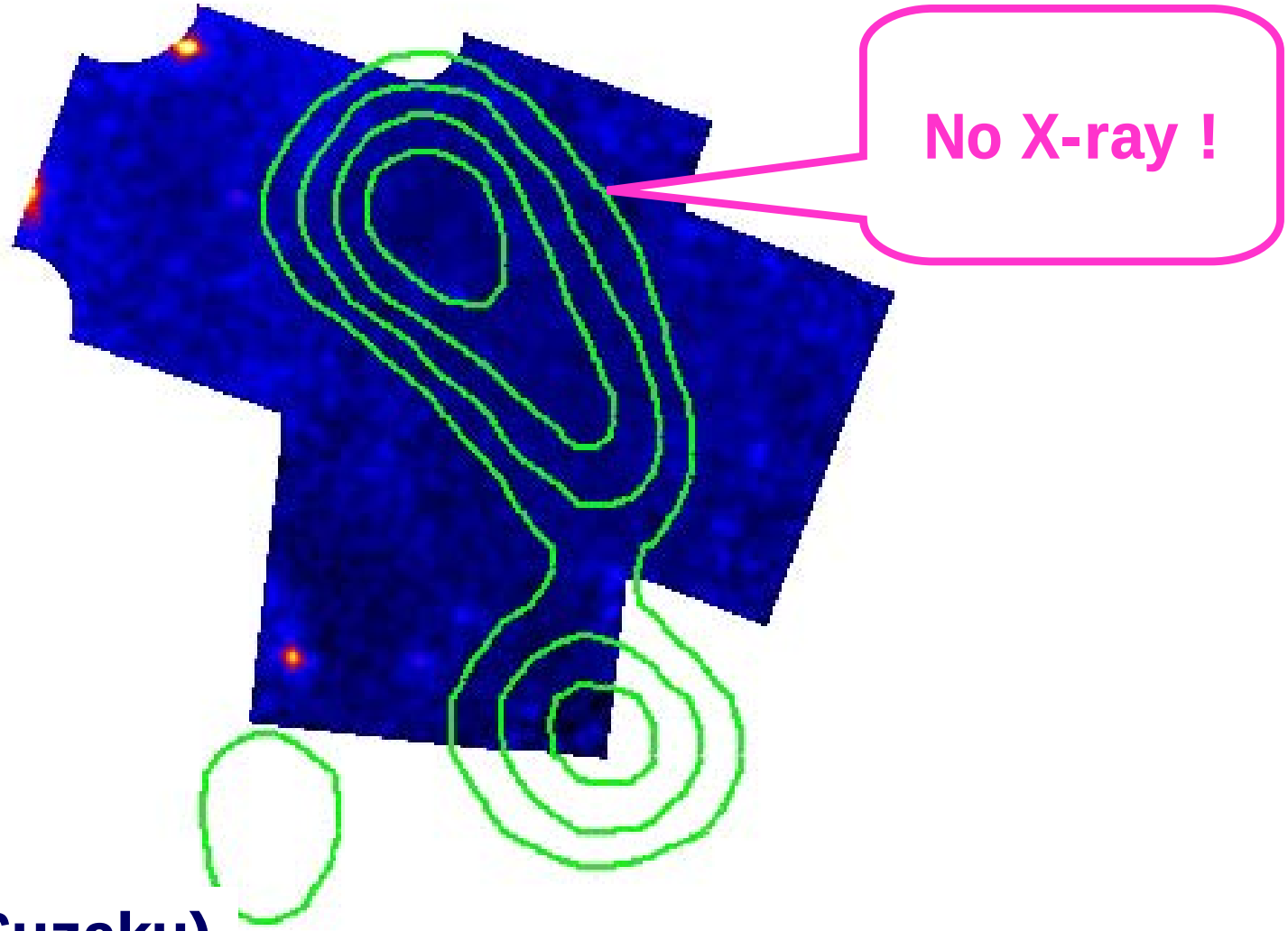
$F_{TeV}/F_X > 32$

Origin is still unknown real dark particle accelerator ?

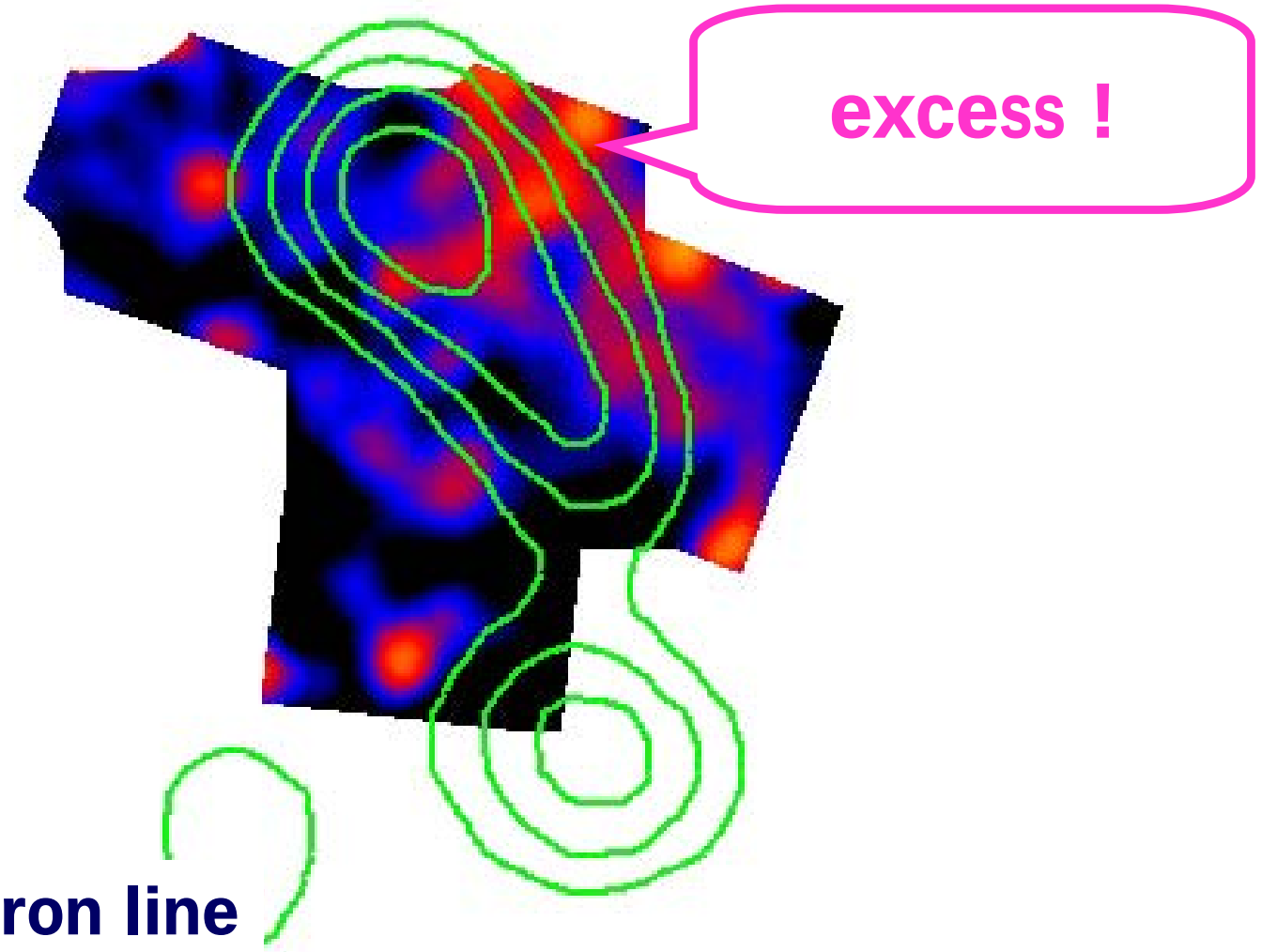
Clue of dark particle accelerator? HESS J1745-303 (1)



Clue of dark particle accelerator? HESS J1745-303 (2)



Clue of dark particle accelerator? HESS J1745-303 (3)



neutral (cold) iron line
(Suzaku)

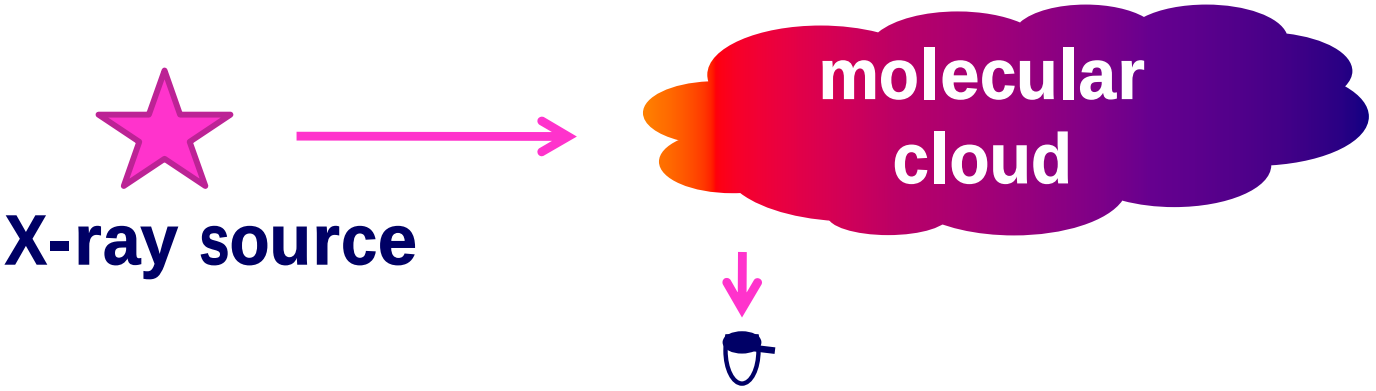
contour: HESS

⟷ 6arcmin

(Bamba+09)

Origin of neutral iron emission line ?

"X-ray reflection nebula"



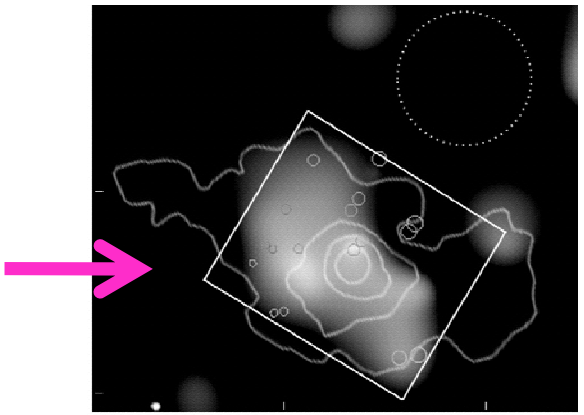
X-ray irradiation -> scattered in MC -> strong emission line from cold iron

X-ray irradiator:

past active GC SMBH itself !

(Koyama+ 2007)

It was very bright 300 years ago.



SgrB2: Murakami+ 2002)

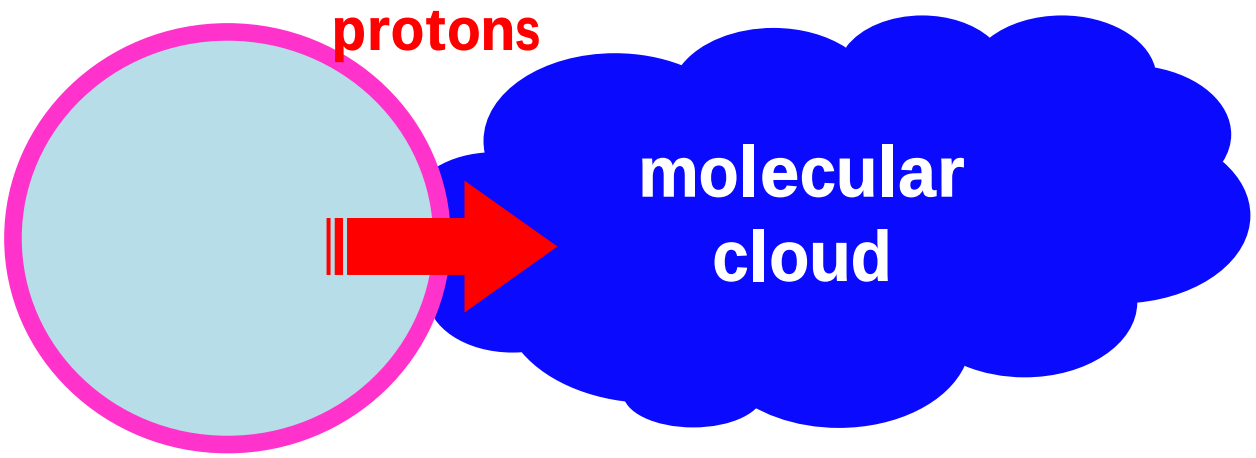
HESS J1745-303 coincides with MC.

(Bamba+09)

SNR + MC = HESS J1745-303 ?

Our scenario

(Bamba+09)



- The SNR G359.1-0.5 is old enough to lose sync. X-rays.
  (Bamba+00)
- This SNR collides with MC. It has OH mesars.
- Protons emit gamma-rays via pi-0 decay.
- Only TeV gamma-rays are observed.
- Dark particle accelerators might be similar sources.

TeV unID list

(TeV Cat: http://tevcat.uchicago.edu/

	category
HESS J1303-631	dark
HESS J1427-608	
HESS J1614-518	PWN?
HESS J1616-508	dark
HESS J1626-490	
HESS J1632-478	
HESS J1634-472	
HESS J1702-420	dark
HESS J1708-410	
HESS J1731-347	SNR?
HESS J1741-302	unknown
HESS J1745-303	dark (+MC SNR)
HESS J1747-281	
HESS J1804-216	dark
HESS J1813-178	PWN
HESS J1825-137	PWN
HESS J1834-087	PWN
HESS J1837-069	PWN
HESS J1841-055	
HESS J1843-033	
HESS J1857-026	
HESS J1858+020	
TeV J2032+4130	PWN

	category
HESS J1640-465	PWN
HESS J1718-385	PWN
HESS J1809-193	PWN
HESS J1833-105	PWN
HESS J1846-029	PWN
HESS J1912+101	PWN
HESS J1923+141	PWN

adding known sources

shell SNR:	1+5
PWN:	23+4
dark:	4
SNR+MC:	1+3
unknown:	1
binaries	4
star forming region	2

Major: PWNe
Sub major: dark/SNR+MC

Fermi detected TeV unIDs !

Fermi bright source catalog (Abdo+09)

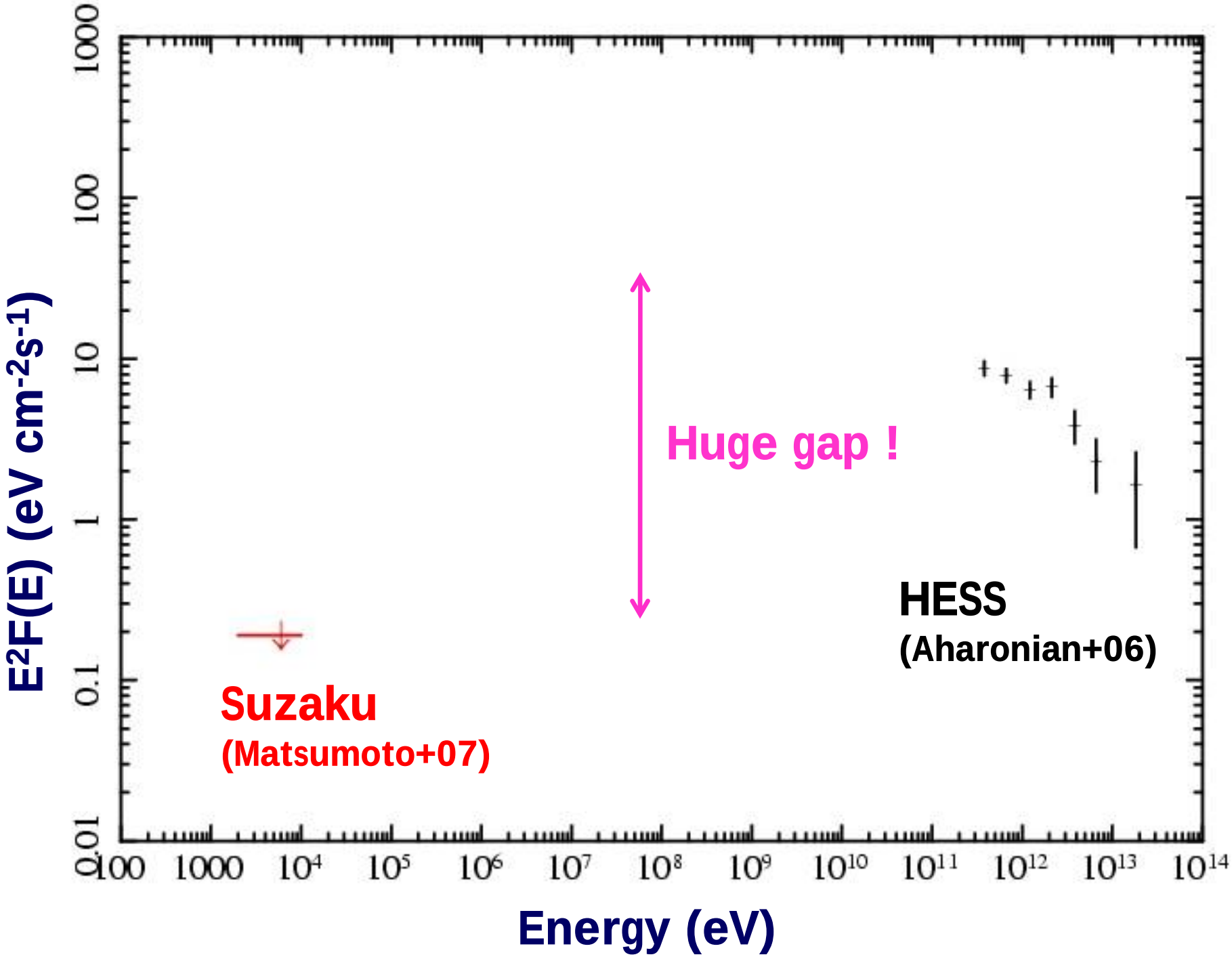
9 of 205 sources coincide with TeV sources

4 % of the Fermi bright sources !!

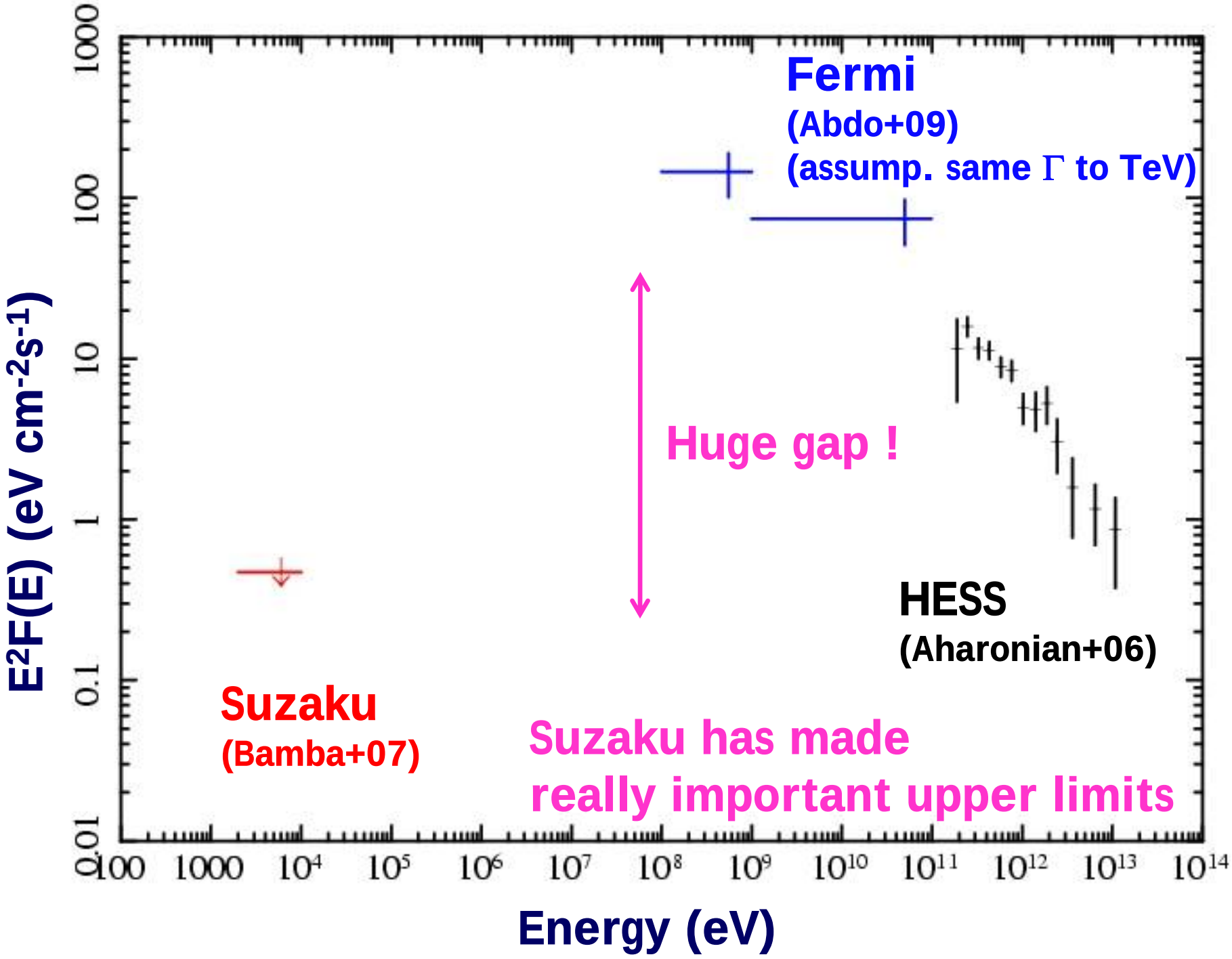
HESS J1023-575	
HESS J1418-609	
HESS J1616-508	dark with Suzaku
HESS J1741-302	unknown
HESS J1804-216	dark with Suzaku
HESS J1813-178	PWN
HESS J1834-087	PWN
HESS J1923+141	
TeV J2032+4230	PWN

Two dark accelerators are bright in GeV

HESS J1616-508 case



HESS J1804-216 case



Origin of the gap ?

Proton accelerators ??

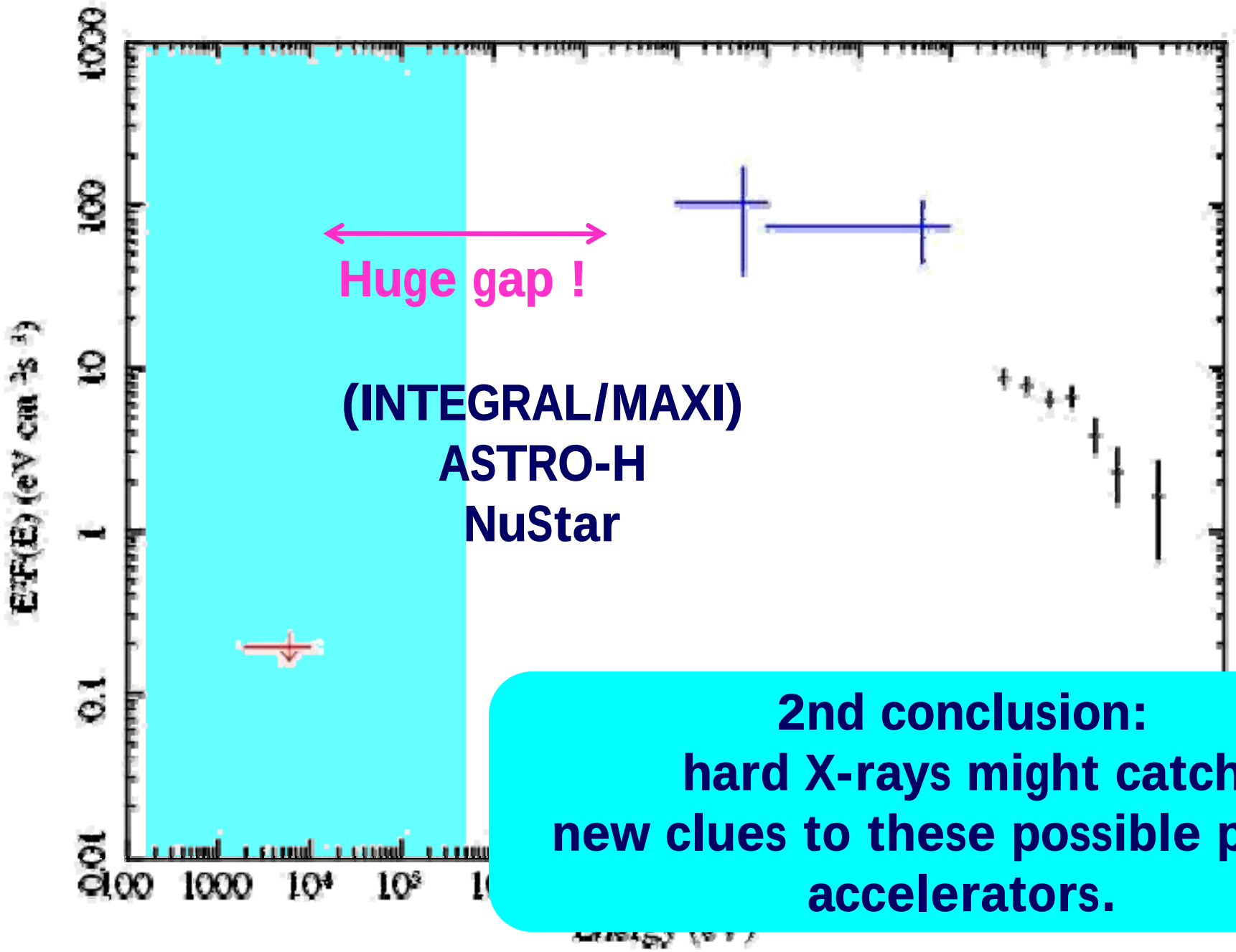
large GeV bump -> pion decay !?
long awaited answer !
photon index is too soft (2.3-2.7)
-> it is very difficult for CRs
due to the softening during propagation ...

X-ray emitters are already moved/disappeared ?

X-rays are from more energetic electrons
than GeV/TeV gamma-rays -> shorter time scale !
PWN/pulsars ?
GeV emission is from pulsars ?
(they are dark in X-rays)
Difficult to prove it ...

Anyhow, making the energy gap of observations
smaller is crucial

Hard X-rays will cover (partly) the gap



2nd conclusion:
hard X-rays might catch new clues to these possible proton accelerators.

Summary

- Suzaku discovered the bending of synchrotron spectra from several SNRs.
- The estimated E_{max} is ~10-100 TeV for electrons. Protons should be accelerated more.

- PWNe could be the main component of TeV unIDs.
- Some TeV unIDs coincides with molecular clouds, which could be proton accelerators.

- TeV unIDs are much brighter in GeV energies. We are waiting for ASTRO-H and NuStar !